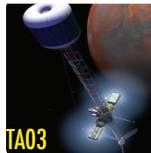


TA01



TA02



TA03



TA04



TA05



TA06



TA07



TA08

TA01 • LAUNCH PROPULSION SYSTEMS

SOLID ROCKET PROPULSION SYSTEMS

- Propellants
- Case Materials
- Nozzle Systems
- Hybrid Rocket Propulsion Systems
- Fundamental Solid Propulsion Technologies

LIQUID ROCKET PROPULSION SYSTEMS

- LH₂/LOX Based
- RP/LOX Based
- CH₄/LOX Based
- Detonation Wave Engines (Closed Cycle)
- Propellants
- Fundamental Liquid Propulsion Technologies

AIR BREATHING PROPULSION SYSTEMS

- TBCC
- RBCC
- Detonation Wave Engines (Open Cycle)
- Turbine Based Jet Engines (Flyback Boosters)
- Ramjet/Scramjet Engines (Accelerators)
- Deeply-cooled Air Cycles
- Air Collection & Enrichment System
- Fundamental Air Breathing Propulsion Technologies

ANCILLARY PROPULSION SYSTEMS

- Auxiliary Control Systems
- Main Propulsion Systems (Excluding Engines)
- Launch Abort Systems
- Thrust Vector Control Systems
- Health Management & Sensors
- Pyro & Separation Systems
- Fundamental Ancillary Propulsion Technologies

UNCONVENTIONAL / OTHER PROPULSION SYSTEMS

- Ground Launch Assist
- Air Launch / Drop Systems
- Space Tether Assist
- Beamed Energy / Energy Addition
- Nuclear
- High Energy Density Materials/Propellants

TA02 • IN-SPACE PROPULSION TECHNOLOGIES

CHEMICAL PROPULSION

- Liquid Storable
- Liquid Cryogenic
- Gels
- Solid
- Hybrid
- Cold Gas/Warm Gas
- Micro-propulsion

NON-CHEMICAL PROPULSION

- Electric Propulsion
- Solar Sail Propulsion
- Thermal Propulsion
- Tether Propulsion

ADVANCED (TRL <3) PROPULSION TECHNOLOGIES

- Beamed Energy Propulsion
- Electric Sail Propulsion
- Fusion Propulsion
- High Energy Density Materials
- Antimatter Propulsion
- Advanced Fission
- Breakthrough Propulsion

SUPPORTING TECHNOLOGIES

- Propellant Storage & Transfer

TA03 • SPACE POWER & ENERGY STORAGE

POWER GENERATION

- Energy Harvesting
- Chemical (Fuel Cells, Heat Engines)
- Solar (Photo-Voltaic & Thermal)
- Radioisotope
- Fission
- Fusion

ENERGY STORAGE

- Batteries
- Flywheels
- Regenerative Fuel Cells

POWER MANAGEMENT & DISTRIBUTION

- FDIR
- Management & Control
- Distribution & Transmission
- Wireless Power Transmission
- Conversion & Regulation

CROSS CUTTING TECHNOLOGY

- Analytical Tools
- Green Energy Impact
- Multi-functional Structures
- Alternative Fuels

TA04 • ROBOTICS, TELE-ROBOTICS & AUTONOMOUS SYSTEMS

SENSING & PERCEPTION

- 3-D Perception
- Relative Position & Velocity Estimation
- Terrain Mapping, Classification & Characterization
- Natural & Man-made Object Recognition
- Sensor Fusion for Sampling & Manipulation
- Onboard Science Data Analysis

MOBILITY

- Extreme Terrain Mobility
- Below-Surface Mobility
- Above-Surface Mobility
- Small Body/Microgravity Mobility

MANIPULATION

- Robot Arms
- Dexterous Manipulators
- Modeling of Contact Dynamics
- Mobile Manipulation
- Collaborative Manipulation
- Robotic Drilling & Sample Processing

HUMAN-SYSTEMS INTEGRATION

- Multi-Modal Human-Systems Interaction
- Supervisory Control
- Robot-to-Suit Interfaces
- Intent Recognition & Reaction
- Distributed Collaboration
- Common Human-Systems Interfaces
- Safety, Trust, & Interfacing of Robotic/Human Proximity Operations

AUTONOMY

- Vehicle Systems Management & FDIR
- Dynamic Planning & Sequencing Tools
- Autonomous Guidance & Control
- Multi-Agent Coordination
- Adjustable Autonomy
- Terrain Relative Navigation
- Path & Motion Planning with Uncertainty

AUTON. RENDEZVOUS & DOCKING

- Relative Navigation Sensors (long-, mid-, near-range)
- Guidance Algorithms
- Docking & Capture Mechanisms/Interfaces
- Mission/System Managers for Autonomy/Automation

RTA SYSTEMS ENGINEERING

- Modularity/Commonality
- Verification & Validation of Complex Adaptive Systems
- Onboard Computing



TA09



TA10

TA05 • COMMUNICATION & NAVIGATION

OPTICAL COMM. & NAVIGATION

- Detector Development
- Large Apertures
- Lasers
- Acquisition & Tracking
- Atmospheric Mitigation

RADIO FREQUENCY COMMUNICATIONS

- Spectrum Efficient Technologies
- Power Efficient Technologies
- Propagation
- Flight & Ground Systems
- Earth Launch & Reentry Comm.
- Antennas

INTERNETWORKING

- Disruptive Tolerant Networking
- Adaptive Network Topology
- Information Assurance
- Integrated Network Management

POSITION, NAVIGATION, AND TIMING

- Timekeeping & Time Distribution
- Onboard Auto Navigation & Maneuver
- Sensors & Vision Processing Systems
- Relative & Proximity Navigation
- Auto Precision Formation Flying
- Auto Approach & Landing

INTEGRATED TECHNOLOGIES

- Radio Systems
- Ultra Wideband
- Cognitive Networks
- Science from the Comm. System
- Hybrid Optical Comm. & Nav. Sensors
- RF/Optical Hybrid Technology

REVOLUTIONARY CONCEPTS

- X-Ray Navigation
- X-Ray Communications
- Neutrino-Based Navigation & Tracking
- Quantum Key Distribution
- Quantum Communications
- SQIF Microwave Amplifier
- Reconfigurable Large Apertures Using Nanosat Constellations

TA06 • HUMAN HEALTH, LIFE SUPPORT & HABITATION SYSTEMS

ENVIRONMENTAL CONTROL & LIFE SUPPORT SYSTEMS & HABITATION SYS.

- Air Revitalization
- Water Recovery & Management
- Waste Management
- Habitation

EXTRAVEHICULAR ACTIVITY SYSTEMS

- Pressure Garment
- Portable Life Support System
- Power, Avionics & Software

HUMAN HEALTH & PERFORMANCE

- Medical Diagnosis / Prognosis
- Long-Duration Health
- Behavioral Health
- Human Factors

ENVIRONMENTAL MONITORING, SAFETY & EMERGENCY RESPONSE

- Sensors: Air, Water, Microbial, etc.
- Fire: Detection, Suppression, Recovery
- Protective Clothing / Breathing
- Remediation

RADIATION

- Risk Assessment Modeling
- Radiation Mitigation
- Protection Systems
- Radiation prediction
- Monitoring Technology

TA07 • HUMAN EXPLORATION DESTINATION SYSTEMS

IN-SITU RESOURCE UTILIZATION

- Destination Reconnaissance, Prospecting, & Mapping
- Resource Acquisition
- Consumables Production
- Manufacturing Products & Infrastructure Emplacement

SUSTAINABILITY & SUPPORTABILITY

- Autonomous Logistics Management
- Maintenance Systems
- Repair Systems
- Food Production, Processing, & Preservation

“ADVANCED” HUMAN MOBILITY SYSTEMS

- EVA Mobility
- Surface Mobility
- Off-Surface Mobility

“ADVANCED” HABITAT SYSTEMS

- Integrated Habitat Systems
- Habitat Evolution
- “Smart” Habitats
- Artificial Gravity

MISSION OPERATIONS & SAFETY

- Crew Training
- Planetary Safety
- Integrated Flight Operations Systems
- Integrated Risk Assessment Tools

CROSS-CUTTING SYSTEMS

- Construction & Assembly
- Particulate Contamination Prevention & Mitigation

TA08 • SCIENCE INSTRUMENTS & SENSOR SYSTEMS

REMOTE SENSING INSTRUMENTS / SENSORS

- Detectors & Focal Planes
- Electronics
- Optical Components
- Microwave / Radio
- Lasers
- Cryogenic / Thermal

OBSERVATORIES

- Mirror Systems
- Structures & Antennas
- Distributed Aperture

IN-SITU INSTRUMENTS / SENSOR

- Particles: Charged & Neutral
- Fields & Waves
- In-Situ

TA09 • ENTRY, DESCENT & LANDING SYSTEMS

AEROASSIST & ATMOSPHERIC ENTRY

- Rigid Thermal Protection Systems
- Flexible Thermal Protection Systems
- Rigid Hypersonic Decelerators
- Deployable Hypersonic Decelerators

DESCENT

- Attached Deployable Decelerators
- Trailing Deployable Decelerators
- Supersonic Retropropulsion

LANDING

- Touchdown Systems
- Egress & Deployment Systems
- Propulsion Systems
- Small Body Systems

VEHICLE SYSTEMS TECHNOLOGY

- Separation Systems
- System Integration and Analyses
- Atmosphere & surface characterization
- Modeling and Simulation
- Instrumentation and Health Monitoring
- GN&C Sensors and Systems

TA10 • NANOTECHNOLOGY

ENGINEERED MATERIALS & STRUCTURES

- Lightweight Structures
- Damage Tolerant Systems
- Coatings
- Adhesives
- Thermal Protection & Control

ENERGY GENERATION & STORAGE

- Energy Storage
- Energy Generation

PROPULSION

- Propellants
- Propulsion Components
- In-Space Propulsion

SENSORS, ELECTRONICS & DEVICES

- Sensors & Actuators
- Nanoelectronics
- Miniature Instruments



TA11



TA12



TA13



TA14

TA11 • MODELING, SIMULATION, INFORMATION TECHNOLOGY & PROCESSING

COMPUTING

- Flight Computing
- Ground Computing

MODELING

- Software Modeling & Model-Checking
- Integrated Hardware & Software Modeling
- Human-System Performance Modeling
- Science Modeling
- Frameworks, Languages, Tools & Standards

SIMULATION

- Distributed Simulation
- Integrated System Lifecycle Simulation
- Simulation-Based Systems Engineering
- Simulation-Based Training & Decision Support Systems

INFORMATION PROCESSING

- Science, Engineering & Mission Data Lifecycle
- Intelligent Data Understanding
- Semantic Technologies
- Collaborative Science & Engineering
- Advanced Mission Systems

TA12 • MATERIALS, STRUCTURES, MECHANICAL SYSTEMS & MANUFACTURING

MATERIALS

- Lightweight Structure
- Computational Design
- Flexible Material Systems
- Environment
- Special Materials

STRUCTURES

- Lightweight Concepts
- Design & Certification Methods
- Reliability & Sustainment
- Test Tools & Methods
- Innovative, Multifunctional Concepts

MECHANICAL SYSTEMS

- Deployables, Docking and Interfaces
- Mechanism Life Extension Systems
- Electro-mechanical, Mechanical & Micromechanisms
- Design & Analysis Tools and Methods
- Reliability / Life Assessment / Health Monitoring
- Certification Methods

MANUFACTURING

- Manufacturing Processes
- Intelligent Integrated Manufacturing and Cyber Physical Systems
- Electronics & Optics Manufacturing Process
- Sustainable Manufacturing

CROSS-CUTTING

- Nondestructive Evaluation
- Model-Based Certification & Sustainment Methods
- Loads and Environments

TA13 • GROUND & LAUNCH SYSTEMS PROCESSING

TECHNOLOGIES TO OPTIMIZE THE OPERATIONAL LIFE-CYCLE

- Storage, Distribution & Conservation of Fluids
- Automated Alignment, Coupling, & Assembly Systems
- Autonomous Command & Control for Ground and Integrated Vehicle / Ground Systems

ENVIRONMENTAL AND GREEN TECHNOLOGIES

- Corrosion Prevention, Detection, & Mitigation
- Environmental Remediation & Site Restoration
- Preservation of Natural Ecosystems
- Alternate Energy Prototypes

TECHNOLOGIES TO INCREASE RELIABILITY AND MISSION AVAILABILITY

- Advanced Launch Technologies
- Environment-Hardened Materials and Structures
- Inspection, Anomaly Detection & Identification
- Fault Isolation and Diagnostics
- Prognostics Technologies
- Repair, Mitigation, and Recovery Technologies
- Communications, Networking, Timing & Telemetry

TECHNOLOGIES TO IMPROVE MISSION SAFETY/MISSION RISK

- Range Tracking, Surveillance & Flight Safety Technologies
- Landing & Recovery Systems & Components
- Weather Prediction and Mitigation
- Robotics / Telerobotics
- Safety Systems

TA14 • THERMAL MANAGEMENT SYSTEMS

CRYOGENIC SYSTEMS

- Passive Thermal Control
- Active Thermal Control
- Integration & Modeling

THERMAL CONTROL SYSTEMS

- Heat Acquisition
- Heat Transfer
- Heat Rejection & Energy Storage

THERMAL PROTECTION SYSTEMS

- Entry / Ascent TPS
- Plume Shielding (Convective & Radiative)
- Sensor Systems & Measurement Technologies

Space Technology Roadmaps STR • TABS

TECHNOLOGY AREA BREAKDOWN STRUCTURE